

WHAT IS CLAIMED IS:

1. A crystallization apparatus comprising: an illumination optical system to emit a light beam having a homogeneous intensity distribution to a non-crystallized semiconductor film, so that the non-crystallized semiconductor film is irradiated with the light beam to crystallize the non-crystallized semiconductor film,

the crystallization apparatus further comprising:  
an optical conversion element which converts the light beam having the homogeneous intensity distribution to a light beam having a periodical upward concave intensity distribution; and

a phase shift mask which passes the light beam, gives a phase difference between parts of the light beam, and converts the light beam having the homogeneous intensity distribution into a light beam having a periodical intensity distribution of an inverse peak type, the phase shift mask having a phase shift portion to determine a position where the intensity distribution of the inverse peak type is minimized,

the optical conversion element being positioned on a light path between the illumination optical system and non-crystallized semiconductor film, the phase shift mask being positioned on the light path between the optical conversion element and non-crystallized

semiconductor film, and the optical conversion element and phase shift mask being positioned so that a minimum position of the upward concave intensity distribution is disposed opposite to the phase shift portion, and

5           the light beam which is converted by the optical conversion element and phase shift mask and with which the non-crystallized semiconductor film is irradiated having the intensity distribution including an inverse peak portion inside an upward concave portion.

10           2. The crystallization apparatus according to claim 1, wherein the phase shift mask and non-crystallized semiconductor film are disposed substantially in parallel with and in the vicinity of each other.

15           3. The crystallization apparatus according to claim 1, further comprising:

          an optical image forming system positioned on the light path between the phase shift mask and non-crystallized semiconductor film,

20           wherein the non-crystallized semiconductor film is distant from a plane optically conjugated with the phase shift mask along an optical axis by a predetermined distance.

25           4. The crystallization apparatus according to claim 1, further comprising:

          an optical image forming system positioned on the light path between the phase shift mask and

non-crystallized semiconductor film,

the optical image forming system having an image-side numerical aperture which is set so as to convert the light beam from the phase shift mask to the light beam which has the periodical intensity distribution of the inverse peak type.

5. The crystallization apparatus according to any one of claim 1, wherein the optical conversion element has a convergence/divergence element including a divergence region in which the light beam from the illumination optical system diverges and a convergence region in which the light beam from the illumination optical system converges to lower a light intensity of the phase shift portion by a divergence function and convergence function.

6. The crystallization apparatus according to claim 5, wherein the divergence region includes a divergence refractive surface on which the light beam diverges by a refraction function, and the convergence region includes a convergence refractive surface on which the light beam converges by the refraction function.

7. The crystallization apparatus according to claim 6, wherein the divergence refractive surface and convergence refractive surface have a one-dimensional refraction function along one direction.

8. The crystallization apparatus according to

claim 6, wherein the divergence refractive surface and convergence refractive surface have a two-dimensional refraction function along two directions crossing at right angles to each other.

5           9. The crystallization apparatus according to claim 6, wherein the divergence refractive surface and convergence refractive surface form a refractive surface which has a sinusoidal wave shape.

10           10. The crystallization apparatus according to claim 9, wherein the refractive surface is formed in a continuous curved surface shape.

11. The crystallization apparatus according to claim 9, wherein the refractive surface is formed in a step shape.

15           12. The crystallization apparatus according to claim 1, wherein the intensity distribution of the light beam with which the non-crystallized semiconductor film is irradiated has an inflection point between the inverse peak portion and upward concave profile.

13. The crystallization apparatus according to claim 1, wherein the convergence/divergence element and phase shift mask are integrally formed to form an integral assembly.

25           14. The crystallization apparatus according to claim 13, wherein the integral assembly includes a phase shift portion in a boundary surface between the

convergence/divergence element and phase shift mask.

15. An optical member comprising: a first optical conversion portion which converts an incident light beam having a homogeneous intensity distribution into a light beam having an upward concave intensity distribution; and a second optical conversion portion which converts the light beam having the upward concave intensity distribution into a light beam having an intensity distribution including an inverse peak portion inside an upward concave portion.

16. A crystallization method of passing a light beam through a phase shift mask, and irradiating a non-crystallized semiconductor film with a light beam having an intensity distribution of an inverse peak type in which a light intensity is smallest in a point corresponding to a phase shift portion of the phase shift mask to form a crystallized semiconductor film, the method comprising:

irradiating the phase shift mask with a light having an upward concave intensity distribution in which the light intensity is lowest in the phase shift portion or in the vicinity of the portion and the light intensity increases as distant from the phase shift portion.

17. The crystallization method according to claim 16, further comprising: disposing the non-crystallized semiconductor film and phase shift mask

substantially in parallel with and in the vicinity of each other.

18. The crystallization method according to claim 16, further comprising:

5 disposing an optical image forming system in a light path between the non-crystallized semiconductor film and phase shift mask; and

10 setting the non-crystallized semiconductor film apart from a plane optically conjugated with the phase shift mask along an optical axis of the optical image forming system by a distance.

19. The crystallization method according to claim 16, further comprising:

15 disposing an optical image forming system in a light path between the non-crystallized semiconductor film and phase shift mask;

20 setting an image-side numerical aperture of the optical image forming system to a required value so as to generate the intensity distribution of the inverse peak type; and

setting the non-crystallized semiconductor film in a plane substantially optically conjugated with the phase shift mask.

20. A crystallization method comprising:

25 converting a light beam having a homogeneous intensity distribution into a light beam having a periodical upward concave intensity distribution;

converting the light beam having the periodical upward concave intensity distribution into a light beam having an intensity distribution including an inverse peak portion inside an upward concave portion; and

5        irradiating and crystallizing the non-crystallized semiconductor film with the finally converted light beam.

21. The crystallization method according to claim 20, further comprising:

10        imaging the light beam having the intensity distribution including the inverse peak portion inside the upward concave portion; and

irradiating and crystallizing the non-crystallized semiconductor film with the imaged light beam.

15        22. A crystallization apparatus comprising:

a light source which emits light beam of a light intensity to melt a semiconductor layer to be treated;

a wavefront dividing element upon which the light beam from the light source is incident;

20        a phase shift mask upon which the light beam from the wavefront dividing element is incident and which emits a light beam having a light intensity pattern; and

a stage which supports a substrate having the semiconductor layer to be treated upon which the light beam from the phase shift mask is incident.

23. A crystallization apparatus comprising:

a light source which emits a light beam of a light intensity to melt a semiconductor layer to be treated;

an optical conversion element which subjects the light beam from the light source to a convergence

5 function and divergence function and which allows the light beam to have a light intensity distribution having a rise/fall of the light intensity; and

an optical system which receives the light beam from the optical conversion element and which allows  
10 the light beam to have a light intensity distribution of a two-steps inverse peak type having the light intensity distribution of the inverse peak type superimposed upon the light intensity distribution having the rise/fall of the light intensity.

15 24. A crystallization method comprising:

a step of allowing a light beam of a light intensity which melts a semiconductor layer to be treated from a light source to be incident upon a wavefront dividing element which divides the light beam  
20 into a plurality of focused parts of the light beam;

a step of allowing the plurality of focused parts of the light beam from the wavefront dividing element to be incident upon a phase shift mask including a phase shift portion having a different phase and  
25 emitting a light beam of a concave light intensity distribution; and

a step of allowing the light beam of the concave



light intensity distribution from the phase shift mask to be incident upon the semiconductor layer to be treated.

25. A crystallization method comprising:

5           a step of subjecting a light beam from a light source which emits the light beam of a light intensity to melt a semiconductor layer to be treated to a convergence function and divergence function and allowing the light beam to have a light intensity  
10           distribution including a rise/fall of the light intensity; and

          a step of allowing the light beam to have a light intensity distribution of a two-steps inverse peak type in which the light intensity distribution of the  
15           inverse peak type is superimposed upon the light intensity distribution including the rise/fall of the light intensity.

26. The crystallization method comprising:

          allowing the light beam transmitted through a  
20           phase shift mask to be incident upon a non-single crystalline semiconductor layer,

          wherein the light beam incident upon the phase shift mask is a light intensity distribution including a rise/fall of a light intensity.

25           27. The crystallization method comprising:

          allowing a light beam transmitted through a phase shift mask to be incident upon a non-crystalline

semiconductor layer to crystallize the layer,

wherein a light intensity distribution of the  
light beam incident upon the non-crystalline

semiconductor layer is a light beam of a light

5 intensity distribution of a two-steps inverse peak  
type.